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SPECIAL FEATURE Education for sustainable development

What has to be learnt for sustainability? A comparison of bachelor engineering education competences at three European universities

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Abstract In a period of harmonisation of the higher education system in Europe, a question is if also learning about sustainability at the universities is converging and what advantages this may have. This paper is an effort to present and advance the work on describing desired sustainability competences for engineering Bachelor graduates in three technical universities (Chalmers in Sweden, DUT in The Netherlands and UPC-Barcelona in Spain) using the European Higher Education Area (EHEA) descriptors. The paper also sheds light on whether there is conformity or not in desired sustainability competences (or in how sustainable development (SD) competences are handled) at the three universities. For universities outside the EHEA, this paper gives hints on the type of sustainability competences that will be required from their first-cycle graduates should they want to continue with second-cycle studies within the EHEA. The results show that the three universities follow a similar pattern in the classification of the competences (Knowledge and understanding, Skills and abilities, and Attitudes) and that there are minor divergences with respect to the list of competences and the levels of learning that Bachelor students should have when graduating. Definition of competences is an area that needs development, and this paper is part of a learning process for the three universities. This study shows that there is improvement potential for all three universities when it comes to being explicit and exact in the description of the desired SD learning.

Keywords Sustainability · Engineering · Education · Competences · Europe

Introduction

Many universities are today actively striving to integrate education for sustainable development (ESD) in their educational activities. Appropriate student learning outcomes, course syllabi, course curricula and assessment methods are some of the things that are in focus. One of the reasons behind the current efforts is the UN Decade of Education for Sustainable Development (DESD, 2005–2014), handled by UNESCO, which has the goal to integrate the principles, values and practices of sustainable development (SD) into all aspects of education and learning. This calls for international cooperation and is one of the reasons behind this paper, which is a joint effort by staff involved in ESD embedment at three European technical universities to present their work on sustainability learning outcomes for engineering graduates. The three universities are Chalmers University of Technology (Chalmers) in Göteborg, Sweden, Delft University of Technology (DUT) in Delft, The Netherlands, and Technical University of Catalonia (UPC) in Barcelona, Spain. They have all demonstrated high ambitions for ESD in

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different activities in the last 2 decades as well as in their current visions (Holmberg et al. 2008).

All three universities are making efforts to adapt according to the so-called "Bologna process"[1] to create a European Higher Education Area (EHEA) till 2010. The goal of this process is to provide tools to connect and compare different educational systems to facilitate exchange (e.g., of students) between the systems. The creation of an effective EHEA asks for the adoption of a system of easily readable and comparable degrees, which requires outcomes-focussed qualifications frameworks that share common and clear methodological descriptors. One of the most important features of the Bologna process is the comparable three-cycle degree system:

- first cycle (Bachelor level 180–240 ECTS[2]);
- second cycle (master level, 90–120 ECTS credits beyond the first cycle, with a minimum of 60 credits at the level of the second cycle);
- third cycle (PhD level).

Traditional models and methods of expressing qualifications structures are now, in the Bologna process, giving way to systems based on explicit reference points using learning outcomes and competences, levels and level indicators, subject benchmarks and qualification descriptors (Bologna Working Group on Qualifications Frameworks 2005). These devices provide more precision and accuracy, and facilitate transparency and comparison. Without these common approaches, full recognition, real transparency and thus the creation of an effective EHEA would be more difficult to achieve. The three technical universities (Chalmers, UPC and DUT) are all struggling to transform and describe their educational programmes and courses according to the goals set up for the EHEA.

Given this context of change, ESD has a window of opportunity to become embedded in the European higher education system. This paper is an effort to present the work done at three universities on describing targeted sustainability competences for engineering graduates using the EHEA descriptors. The paper will mainly focus on first-cycle learning outcomes. The paper also sheds light on whether there is conformity or not in desired SD competences (or in how SD competences are handled) at the three universities. For universities outside the EHEA, this paper gives hints on the type of sustainability competences that will be required from their first-cycle graduates should they want to continue with second-cycle studies within the EHEA.

For the three universities, this paper is also an international benchmarking process that aims at advancing their internal work on improving quality in ESD.

Competences within the EHEA framework

In order to contribute to the elaboration of a framework with comparable and compatible qualifications in each of the signatory countries of the EHEA, the project Tuning Educational Structures in Europe (González and Wagenaar 2003) was developed. This project states that competences represent a dynamic combination of cognitive and metacognitive skills, knowledge and understanding, interpersonal, intellectual and practical skills, and ethical values. For a person to have a competence (or live up to a learning outcome), he or she must be able to put into play a certain capacity or skill and perform a task, where he or she is able to demonstrate the ability to do so in a way that allows evaluation of the level of achievement.

There are different competence taxonomies (González and Wagenaar 2003; Joint Quality Initiative 2004; Sterling 2004). In our work the description of competences embraces three strands:

- "Knowing and understanding": theoretical knowledge of an academic field, the capacity to know and understand.
- "Skills and abilities": practical and operational application of knowledge to certain situations.
- "Attitude": a complex mental state involving beliefs, feelings, values and dispositions to act in certain ways.

Within a degree programme, competences can be differentiated among subject-specific competences related to a field of study and generic competences common to any degree course. This work focusses on generic SD competences of first-cycle degrees.

With the aim of evaluating competences and comparing the depth required for these competences for students graduating with a Bachelor degree from the three universities, the Bloom's and Krathwohl's taxonomy categories are used (Bloom 1956; Krathwohl et al. 1973).

Bloom identified six levels within the cognitive domain, from the simple recall or recognition of facts as the lowest level, through increasingly more complex and abstract mental levels, to the highest order, which is classified as evaluation:

1. *Knowledge*: recall data or information.
2. *Comprehension*: understand the meaning, translation, interpolation and interpretation of instructions and problems. State a problem in one's own words.
3. *Application*: use a concept in a new situation or unprompted use of an abstraction. Apply what was

[1] This name comes from the Bologna Declaration (1999) (http://ec.europa.eu/education/policies/educ/bologna/bologna_en.html).

[2] ECTS (European Credit Transfer System) is the unit for a students' work load, and 60 ECTS normally corresponds to 1 year of fulltime studies ≈1,500 h of student work.

learned in the classroom into novel situations in the work place.
4. *Analysis*: break concepts or material into constituent parts, determining how the parts relate to one another and to an overall structure.
5. *Synthesis*: build a structure or pattern from diverse elements. Put parts together to form a whole, with emphasis on creating a new meaning or structure.
6. *Evaluation*: make judgments about the value of ideas or materials.

In our work, the cognitive levels are applied to the competences related to knowledge and understanding and skills and abilities.

When evaluating the affective domain, which includes the manner in which we deal with things emotionally, such as feelings, values, appreciation, enthusiasms, motivations, and attitudes, Krathwohl et al. (1973) defined a set of five major categories, which we use to evaluate attitudes learning domain competences. These categories are listed from the simplest behaviour to the most complex:

1. *Receiving*: be aware of or sensitive to the existence of certain ideas, material or phenomena, and being willing to tolerate them.
2. *Responding*: commit in some small measure to the ideas, materials or phenomena involved by actively responding to them.
3. *Valuing*: attach value to an object, phenomenon or behaviour. Demonstrate a positive attitude, appreciation, belief or commitment through expression or action.
4. *Organisation*: organise (compare, relate and synthesise) different values into the beginning of an internally consistent value system. Recognise a need to balance freedom and responsibility. Formulate a career plan. Adopt a systematic approach to problem solving.
5. *Characterisation by a value or value complex*: have a pervasive, consistent and predictable manner. Work independently and diligently. Practice cooperation in group activities. Act ethically.

Before analysing the competences on SD that have been developed for the Bachelor level at each university, the next section situates the context in which these have been developed.

Case descriptions

Chalmers

National context

Chalmers University of Technology (Chalmers) is obliged to follow the Swedish law for higher education, which includes, since February 2006, a requirement that all higher education in Sweden should contribute to promoting SD. However, what this means in practice has not been fully established yet.

Chalmers has several Bachelor (3 years) and Master (5 years) of Science in engineering programmes and has to follow the Swedish Degree Ordinance for these engineering degrees. For the Master of Science in engineering degree, this means, e.g., that: "the education should give prerequisites for students to gain knowledge and skills in designing products, processes and work environment with respect to human possibilities and needs as well as to societal goals regarding social conditions, resource use, environment and economy". The Swedish Agency for Higher Education made an evaluation of all Master of Science in engineering programmes in Sweden in 2005, in which all programmes were criticised for insufficient education on sustainable application of technology. In the next evaluation, in 2011, special emphasis will be put on measures that have been taken to accomplish this requirement in the Swedish Degree Ordinance.

The universities in Sweden are working independently on ESD issues, but there are conferences and networks that can be used for exchange of experiences. The Swedish Agency for Higher Education arranges an annual national quality conference in which ESD is a natural part. Another relevant annual national conference is organised by the Swedish Research Association for SD (in short VHU), which was founded in February in 2004. The aim of VHU is to create a forum for discussion, interaction and cooperation among active scientists as well as individuals and organisations in society. A Swedish network, HU2, was initiated in 2006 with the aim of integrating SD in higher education. The network invites anyone working within education and organisation at universities, as well as relevant authorities and student organiations, and there is an ambition to have a meeting every half year. A project (NLHU2) about SD learning outcomes for the first and second cycles has been conducted in connection to the network. In January 2008, a Swedish International Centre of Education for SD (SWEDESD[3]) was started. The Centre is financed by the Swedish International Development Cooperation Agency (SIDA), and its purpose is to facilitate and support education and learning in the field of SD.

University context

Chalmers has recently adopted a new vision: "Chalmers—for a sustainable future". In line with this vision, Chalmers is actively promoting ESD in its Bachelor and Master's

[3] http://mainweb.hgo.se/ext/swedesd.nsf/($all)/4CAE61CDCBF50A55C12573DF0036AC0A?OpenDocument.

programmes. There is no Bachelor programme that is specialised on SD, but the choice at Chalmers has been to strive to integrate SD into all programmes. There is a local requirement (that originates from a policy created already in 1985) that the Bachelor curriculum in all educational programmes should contain a compulsory course of five full-time weeks of studies, i.e., 7.5 ECTS, focussing on environment and SD. A first description of a desired content in such courses was elaborated by teachers in environment and SD in 2005. This is described elsewhere by Lundqvist and Svanström (2008). An additional local requirement is that all five-year programmes must include 7.5 ECTS of courses in humanistic and social sciences (excluding economy and languages). There is a connection and some overlap between the two requirements, and together they cover environmental and social aspects of SD. In this paper, only the first of the two requirements mentioned is evaluated.

The board at Chalmers decided in April 2006 to start a 3-year project with the purpose of creating an organisation for handling issues related to learning and ESD[4] (ESD project 2008; Svanström et al. 2008a). The competences or learning outcomes for SD that are presented and analysed in this paper have been developed within this project and are suggested as learning outcomes for the local requirement in environment and SD at Chalmers. They are based on earlier work and have been developed in contact with teachers, programme directors, students and people in the educational organisation at Chalmers. However, the text will be reformulated based on the latest comments from this group. The current version was seen as slightly too ambitious for the first cycle (Bachelor level). The compulsory course in environment and SD at Chalmers is only a minimum requirement, and the overall goal at Chalmers is that ESD becomes embedded in all educational programmes and penetrates all courses. Within the ESD project, a resource group has the task to motivate and support teachers and programme directors, through individual interaction, to integrate ESD in courses and programmes (Holmberg et al. 2008). ESD quality and embedment are being discussed at regular meetings at Chalmers involving different actors.

A new centre on learning for SD in technological sciences will be started at Chalmers in the near future. The purpose is to strengthen learning for SD within technological sciences by spreading information, supporting and organising different activities, and starting up research within the field. Efforts will address internal learning activities at Chalmers as well as public learning and learning in elementary and high schools. The centre will take on the main responsibility for ESD issues at Chalmers.

[4] http://www.chalmers.se/gmv/EN/projects/esd_chalmers.

Delft University of Technology

National context

In The Netherlands, the Brundtland report of 1987 inspired the government to redirect environmental policies towards SD. This was expressed in the first National Environmental Policy Plan (NEPP in 1989). The aim was to achieve "Sustainable Netherlands" within one generation. By law, the government was obliged to prepare a National Environmental Policy Plan every 4 years. In the second plan period, the governmental research programme "Sustainable Technology Development" (1993–1998) was started up. It aimed at studying whether and how it would be possible to initiate innovation processes to create sustainable options to provide for people's needs in the next generations (long term, up to 50 years) (Weaver et al. 2000). In this programme hundreds of participants from the Dutch Technology Community "learned by doing". In the third plan period, the programme "Economy–Ecology–Technology" was institutionalised to set up projects to integrate economy, ecology and technology on medium terms: time to market 5–10 years. In the fourth plan, transition policies were launched to overcome persistent problems in the fields of energy, mobility, agriculture and biodiversity. In the early years of the new millennium, during the execution of the fourth plan, a government change put the attention to SD and the willingness to provide budgets under pressure. However, the urgency of climate change and rising energy prices soon reversed this trend.

University context

DUT was founded in 1842, as the first (and still the largest) institution to train academic engineers in The Netherlands. Its engineering training programmes were for a long time renowned, but rather technocratic. The uproars of the 1970s affected DUT considerably. By the introduction of new legislation in 1972, students and assistants could participate in the university decision-making processes. By the end of the 1970s, environmental issues had affected some engineering curricula, although only marginally affected most other engineering curricula at DUT. The Brundtland report and the first NEPP of The Netherlands triggered a second wave of environmental awareness at DUT. This renewed interest in environmental issues resulted in some new initiatives, but they were all add-on. There were barely any changes in the major programmes of engineers, nor in research programmes, while at the same time, in the framework of the NEPP, important tasks were assigned to universities. In 1991, DUT adopted an environmental policy plan. This plan included the introduction of an environmental management system and more scope for environmental issues in education and research. To implement this, a high-level steering group chaired by Prof. Marcel de Bruin, head of the nuclear reactor institute, was formed. This steering group aimed at introducing 'SD' throughout the engineering curricula. However, the steering group's report did not lead to significant changes in the study programmes of DUT.

An important external event was that the government had consented in 1994 to 5-year curricula for engineers,[5] and so there was scope for new courses. This scope was not to be filled by extra technology courses. Social skills of engineers were often regarded to be less than sufficient, and therefore developing social skills became important. Moreover, it became politically unacceptable that most students spent more years studying than the official length of their study programmes. It was with this background that a new Committee for SD at DUT was installed in 1996. The committee's assignment was both to advise on and to implement the integration of SD in both the education and research programmes of DUT. As the objective was to advise on integration in all study programmes, all study programmes had to be represented in the committee while at the same time the committee members should have a considerable teaching task, knowledge of (the impact of) SD and standing within the university community.

The committee regarded as its first goal to bridge the gap between (traditional) 'environmentalism' and 'engineering': SD had to become a challenge for engineers and the engineering profession. In line with the strategic vision of DUT, engineers graduated from DUT had to be prepared for the great technological challenges, especially solving questions related to SD. This implied that DUT had to educate engineers who could make 'SD' operational in technical scientific designing and in the application of technology and technical systems. In November 1997 the committee proposed a plan consisting of three interconnected operations:

1. The design of an elementary course 'Technology in SD' for ALL students of the DUT.
2. The integration of SD in ALL regular disciplinary courses in a way corresponding to the nature of each specific course.
3. The development of a possibility to graduate in a SD specialisation within the framework of each department.

From the start, the committee closely cooperated with the departments in a process of 'learning by doing'. In 1998, the learning objectives for a basic SD course at DUT were formulated.

Technical University of Catalunya, UPC-Barcelona

National context

The pressure from the national higher education legislation towards sustainability at universities has been almost nonexistent in Spain. In the Bologna reform process, efforts have mainly been focussed on the potentially strong reorganisation of the curriculum in order to merge two different types of engineering schools (3 and 5 years long) and develop a framework that might be compatible to the EHEA.

This difficult reform has left little space for other profound debates, such as the ESD one. In that panorama, only very few universities have tried to develop a particular profile related to environment or sustainability, such as at UPC. This university has been one of the few pushing the Ministry of Education through the Spanish Rector's Conference to create some demand from the legislation and available resources in that direction (Comité Ejecutivo del Grupo de Trabajo de Calidad Ambiental y Desarrollo Sostenible de la CRUE 2005), though without seeing any results yet.

University context

UPC has shown a proactive approach towards the inclusion in courses and programmes of environmental aspects (from 1996 to 2005), and currently SD issues through its institutional strategic plans (Ferrer-Balas 2004; Holmberg et al. 2008). Within the period 1996–2005, curriculum greening was approached as an incremental change, and environmental aspects where included within the curricula. However, these remained basically unchanged, and the students that are trained today do not differ significantly regarding sustainability competences from those in the 1990s.

In 2006, with the help of an international expert's evaluation and an internal participatory process (Ferrer-Balas and Barceló 2008), UPC initiated a new strategy, called UPC Sustainable 2015, which aims to be a further step. External links and the explicit orientation to sustainability and to long-term issues are the core elements that should help to move more rapidly towards a new sustainable paradigm in technical education.

The new strategy is linked to the Bologna process and aims to take advantage of this window of opportunity. UPC is reorganising all its degrees to the new model and thus has created, in this order, a number of new Masters programmes, and will start, in year 2009/2010, all its new Bachelors. While at the Masters level, new programmes on

[5] Thereby reversing the 1984 decision that all academic programs in The Netherlands should be 4 years.

SD have been created, a key issue that remains is how the transversal integration of SD at the Bachelor level will be done. For that, during the transition period, a series of activities has been developed, such as the individual interaction with lecturers (Holmberg et al. 2008) or the organisation of participatory debates on sustainability and technical education. From these processes, two framework documents were derived: UPC's Declaration of Sustainability and a framework for the introduction of SD in Bachelor programmes. The documents have been validated officially, together with the approval in 2008 that "sustainability and social commitment" is a compulsory transversal competence for all UPC Bachelor programmes. These documents are initial ESD guidelines for the schools and faculties that have to design their own degrees, and include the general competences and learning outcomes regarding SD that any Bachelor graduate should acquire, which are those analysed in this study.

Results and discussion

As has been presented in the descriptions above, the three universities developed through different processes and in different periods their sets of SD competences in the learning domains for Bachelor programmes, which are the core objects of study in this work. Tables 1, 2 and 3 show the sets of sustainability competences of each university in the three learning domains (Knowledge and understanding, Skills and abilities, and Attitudes), clustered by key words, with their level of learning according to Bloom's taxonomy (BT) for cognitive learning (1-Knowledge, 2-Comprehension, 3-Application, 4-Analysis, 5-Synthesis and 6-Evaluation) and to Krathwohl's taxonomy (KT) for affective learning (1-Receiving, 2-Responding, 3-Valuing, 4-Organisation and 5-Value complex) as indicated.

Commonalities and differences in learning outcomes/ competences

The analysis of *Knowledge and understanding* learning competences (Table 1) shows that there is significant consensus concerning the type of competences that are considered by the three universities. Only one competence is identified at just one university ("world current situation", at UPC). The others are shared. Figure 1 highlights graphically the levels of learning under Bloom's taxonomy. It is important to underline that the maximum level of learning in this domain is *Comprehension* (*2*) because, in fact, understanding is its main intention. Note that both Chalmers and DUT have additional sets of required competences for the science, technology and society area, which are not included in this analysis.

In relation to skills and abilities learning competences, Table 2 illustrates that there is an important consensus also for this area, both in the list of competences and in their level of learning. In Fig. 2 we can see that universities ask for the maximum level of learning for the competences related to systemic thinking, critical thinking and social participation, meanwhile self-learning, cooperation and SD problem solving are at the application level of learning.

Finally, the analysis of *attitudinal* competences, Table 3, reveals that those competences are described in different ways at the three universities, which makes it more difficult to find appropriate key words that encompass the targeted learning. There is complete consensus only in that students should attain a certain level of concern or awareness of risks (Fig. 3).

The key words that were picked out to describe the competences can form the basis for a discussion on how descriptors could be described and can be used by other universities for benchmarking and learning. In another analysis of learning outcomes for ESD (Svanström et al. 2008b), some commonalities that were found concerned systemic or holistic thinking, the integration of different perspectives and skills related to problem solving, critical thinking, creative thinking, self-learning, communication and team work. In the attitudes area, ethics, concern, participatory decision-making and democratic principles are some of the key issues that were described. The competences listed for the three universities in this paper are in line with generic ESD competences listed in the referred paper.

Barriers for consensus in competences

When analysing the list of competences of the three universities, the main barrier in looking for commonalities among the three institutions is the way the competences are described. Sometimes the competences embrace a full branch of actions and sub-competences (e.g., *Critical thinking*), and in other examples the competences are described as a specific action (e.g., *Ability to separate facts from values*). This divergence of competences description complicates their classification under a common descriptor key word, as proposed in Tables 1, 2 and 3. It should be mentioned that some of the authors have been directly involved in the definition of competences at their own universities, which made it possible to go behind the text and discuss the original intentions. In spite of the differences in descriptions, it was therefore possible to find a common language to analyse and compare the sets of competences. However, this reveals that the engineering academic community is not yet used to working with SD descriptors for competences and that this work can

Table 1 Knowledge and understanding competence analysis

Keyword	DUT	BT[a]	UPC	BT	Chalmers	BT
World current situation		0	To understand the current situation of the world and the challenges of our society from a sustainability perspective	2		0
Causes of unsustainability	Have a global insight into the mechanisms that underline sustainability problems	2	To know the causes that have brought society to the current un-sustainability and specially the role of technology	1		0
Sustainability fundamentals	Have knowledge of the concept and the framework of the concepts related to sustainable development and can see the relation between their knowledge and skills and this societal challenge	2	To know the fundamentals of the Sustainability and Human Development paradigm	1	Knowledge about the sustainable development concept and political ambitions	1
Science, technology and society	Have an understanding of the relation of technical systems and subsystems and of the social factors that partly determine the performance of a technology in practice Have a global insight into the technical and scientific dimensions of sustainable development and are aware of the economical and social dimensions Acquiring understanding of the interrelation between product, process and environment, and the dynamics of technological change	2	To know how the scientific and technological developments have helped to cover the basic needs and the development of environmental transformation capacities	1	Knowledge of the interface between the focus area of the profession and natural and social systems (environmental impacts at large)	1
Instruments for sustainable technologies	Knowledge of the main topics and models that can be applied to the use of technology to achieve integrated ecological and technological objectives	1	To know the basic tools and strategies to the introduction of sustainability criteria in the final thesis work and in the development of the profession	1		0

[a] Cognitive Bloom's Taxonomy (BT 1-knowledge, 2-comprehension, 3-application, 4-analysis, 5-synthesis, 6-evaluation)

contribute to their development and to their integration into Bachelor programmes.

Despite the differences in the list of competences and in the required levels of learning among the three institutions, it is clear that there are significant commonalities. The differences, however, point at areas that should be reviewed at each of the universities. The reason behind differences is likely not always differing opinions on what should be included, but rather that competences are formulated in different ways by different people and also reflect the culture in which they were formed. This paper is therefore part of an important learning process on how to formulate SD competences in a comparable way, but also on how to be explicit about the required learning, also for things that in a certain culture goes without saying.

Should all degrees have the same targeted competences? Pretending to completely homogenise sustainability competences with the purpose of freedom of mobility is perhaps unrealistic, and even undesirable. For example, a certain profile linked to the cultural aspects of a country may be obtained by including certain competences (particularly attitudinal) that may differentiate one programme from the others.

Table 2 Skills and abilities competence analysis

Keyword	DUT	BT[a]	UPC	BT	Chalmers	BT
Self-learning		0		0	Self-learning	3
Cooperation and transdisciplinarity	To cooperate with other technical and non-technical disciplines in designing and managing technical systems, and to communicate adequately with other stakeholders/actors in the surrounding of the technical system in question	3	Empathy, dialogue and cooperation	3	Communication and cooperation with different actors	6
	To recognise the causes of sustainability problems not only at the level of subsystems, but also are able to overcome their disciplinary boundaries in creating structural solutions				Ability to handle shifts in perspectives (interdisciplinarity, dynamics over time, local and global considerations, geographical differences and cultural, social and political perspectives)	
SD Problem solving	Ability to apply knowledge and understanding in the engineering praxis	3	Ability to solve problems and develop projects under the Sustainability paradigm	3	Problem solving	5
Systemic thinking	Are capable of identifying directions for solutions for sustainability questions, and have an understanding of the implications of possible solutions:	4	Systemic thinking	6	Ability to identify systems—to think holistically in order to be able to handle complexity and balance between different dimensions of SD (to discern patterns, to understand cause-effect relationships, to understand conceptual models of systems, etc.)	4
	• In the long term					
	• In other scale levels (geographically)					
	• In other system levels					
Critical thinking	Are capable to make a sound judgement between different directions of solutions, taking into account:	6	Critical thinking	6	Ability to reflect on the professional role and responsibility as well as citizenship in relation to SD in a structured way	4
	• Uncertainties				Critical and creative thinking	
	• The dynamics of the technology				Ability to separate facts from values	
	• The interest of different actors				Ability to identify ethical dilemmas and make decisions based partly on ethical considerations (accept that the decision may be based on both facts and ethical considerations)	
Social participation		0	Promote the social participation	6	Participatory decision-making, to be able to use democratic principles	6

[a] Cognitive Bloom's Taxonomy (BT 1-knowledge, 2-comprehension, 3-application, 4-analysis, 5-synthesis, 6-evaluation)

Next step/further work

The analysis of competences showed divergences in their descriptions, which makes it difficult to benchmark the programmes in different universities. Nevertheless, the aim of listing competences is to make clear and understandable the learning of a certain programme; therefore, for the sake of transparency, a common language when describing competences must be agreed upon.

A next step of work would be to try to find a common framework of competences in relation to SD in engineering Bachelor degrees in order to facilitate students' and professionals' mobility both within Europe and outside Europe. Once these minimum common competences are

Table 3 Attitudes competence analysis

Keyword	DUT	KT[a]	UPC	KT	Chalmers	KT
Responsibility/commitment/SD challenge acknowledge	Acknowledge the challenge to contribute from their profession to sustainable development	3		0	Commitment to SD—important for active participation, self-discipline and changed behavioural patterns	5
Respect/ethical sense/peace culture		0[b]	Ethical sense and consciousness of the human and professional activity Peace culture	4		0
Concern/risk awareness	Are aware of the risks of the unsustainable use of resources that are available for mankind	3	Respect for the past, current and future generations Respect for the environment Respect for the diversity	3	Concern for SD	3

[a] Affective Krathwohl's Taxonomy (KT 1-receiving, 2-responding, 3-valuing, 4-organisation, 5-value complex)

[b] In TU Delft ethics competences are not included specifically within Sustainability because they have their own domain in the degrees description

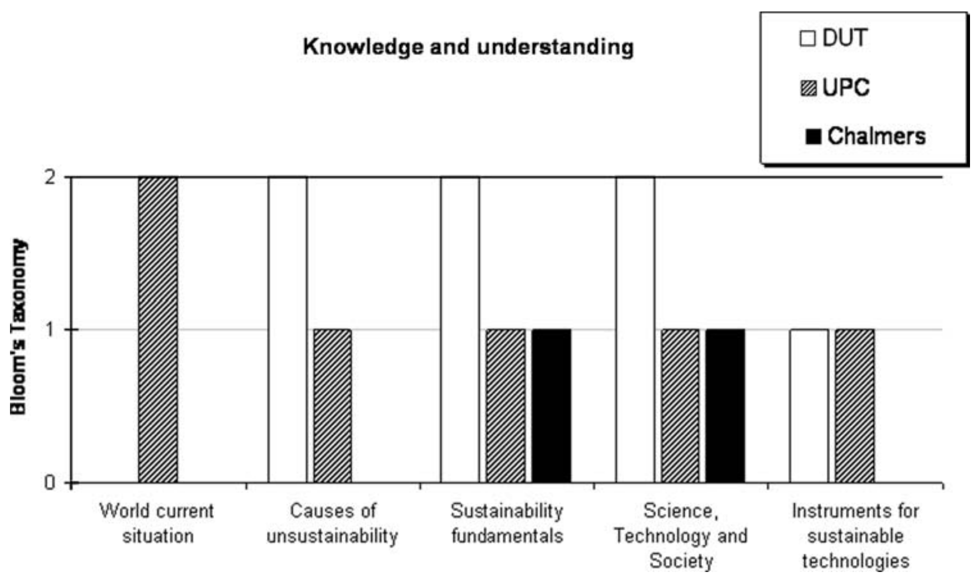

Fig. 1 Knowledge and understanding competence levels of learning

specified, their assessment in a comparable way will also be necessary.

Conclusions

This paper has presented the sustainability competences for engineering Bachelor graduates in three technical universities (Chalmers in Sweden, DUT in The Netherlands and UPC-Barcelona in Spain) using the European Higher Education Area (EHEA) descriptors. The cross-comparison, using Bloom's taxonomy, as well as a key words grouping of competences has allowed the observation of similarities and divergences in the way the three universities formulate (and prioritise) what has to be learnt in SD at the bachelor level.

It has been shown in this study that there is a strong convergence in the fundamental meaning of competences, although scarce matching among the descriptions formulated. The authors do not think that the SD competences should in the end be the same in favour of mobility and exchange; however, progress needs to be made towards a more similar description for allowing the EHEA system to make use of the transferability of European degrees, also in the domain of SD. More than homogeneity, what is missing is harmoniousness.

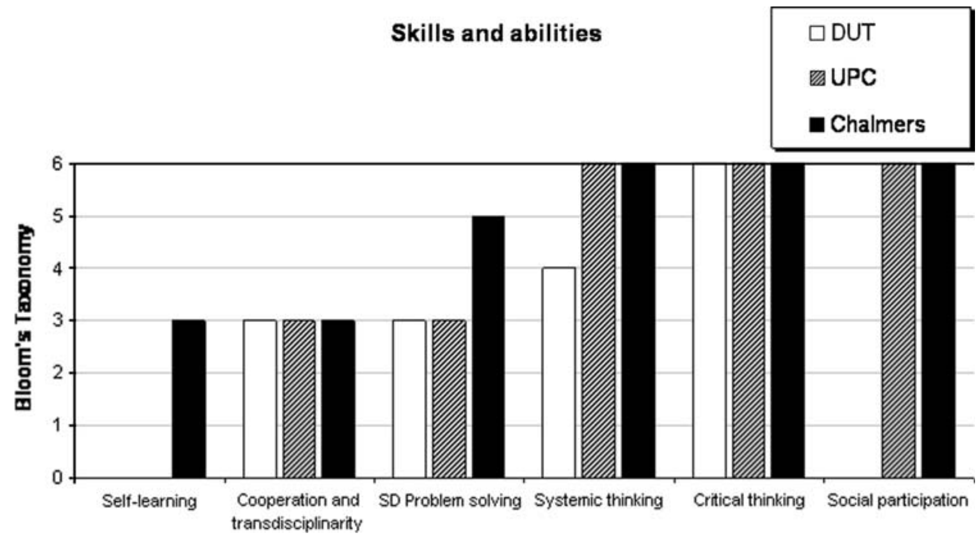

Fig. 2 Skills and abilities competence levels of learning

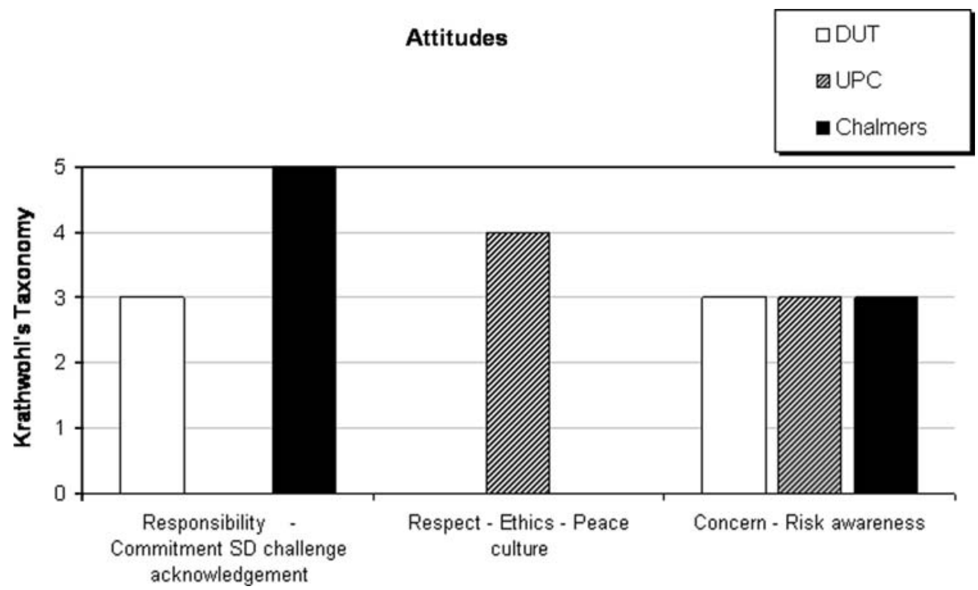

Fig. 3 Attitudes competence levels of learning

An explicit and precise description of SD competences in engineering education degrees is necessary in order to increase the transparency and comparability of curriculums and, thus, the recognition of degrees. This description of SD competences would also provide a common language among faculty that would indeed make the Sustainability concept more intelligible.

The definition of competences is a learning process. This study makes us aware that the definition of SD competences still has to be much improved in order to facilitate their integration in the engineering curricula.

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